ABoVE
Carbon Dynamics Working Group

Abhishek Chatterjee, S. Natali, R. Commane (co-chairs)

E. Larson, Z. Liu, B. Poulter, B. Rogers, L. Schiferl, C. Sweeney, K. Turner, J. Watts, Z. Zhang, et al.

ABoVE Science Team Meeting

La Jolla, May 21, 2019

Outline

- ABoVE Carbon Dynamics WG
- Carbon cycle legacy in BOREAS
- Outstanding carbon cycle Questions

  (pooled from various projects and their goals)
- Project Updates

ABoVE Projects with CD Component

Primary Discipline:

Abshire (2017)
Byrne (NPP 2018)
Gamon (TE 2014)
Hu (TE 2018)
James (NSF 2017)
Keeling (CARBON 2016)
Kimball (TE 2014)
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Secondary:

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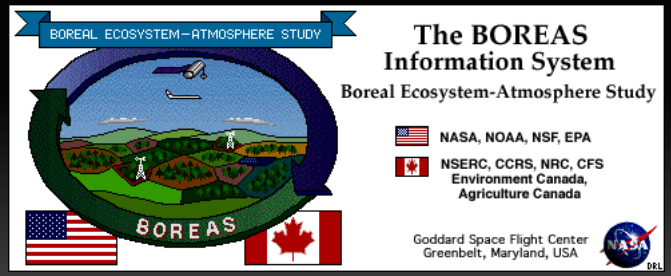
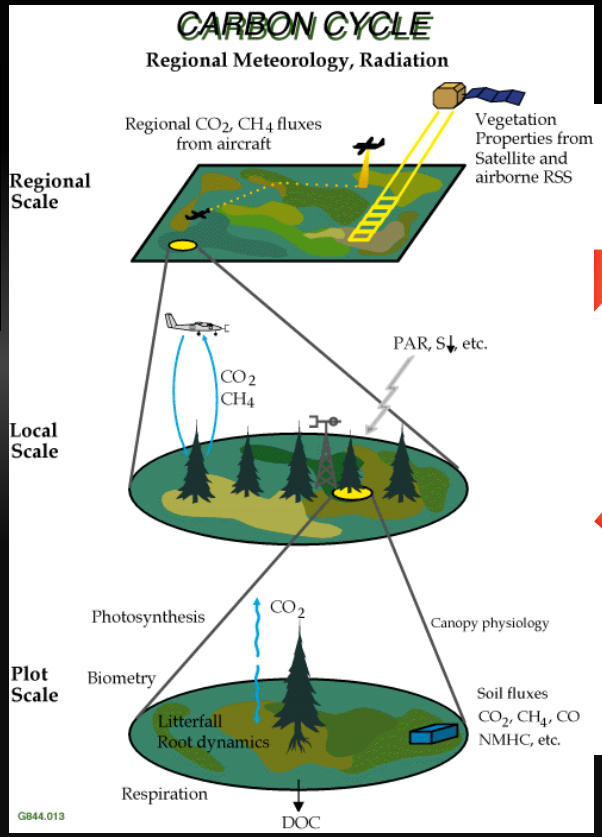
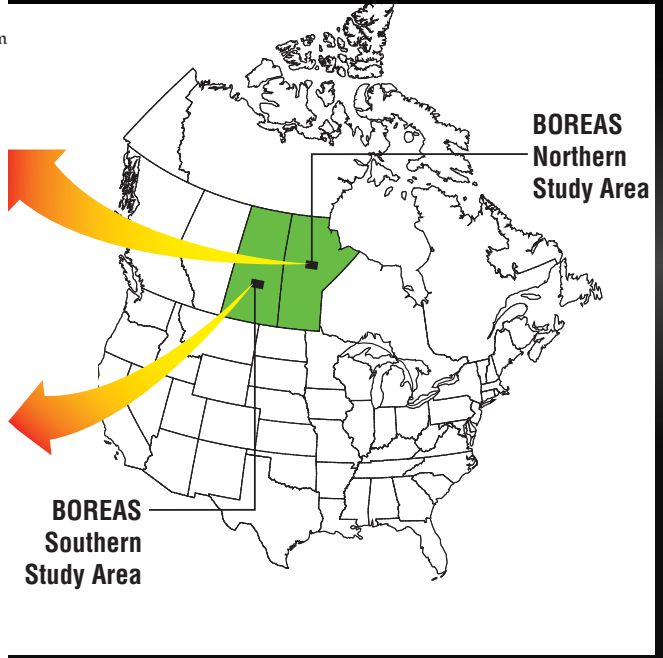
Tabatabaeenejad (TE 2016)
Townsend (TE 2018)
Turner-K (2007)
Veraverbeke (2018)
Vierling (TE 2011)
Watts (NIP 2017)
Wullschleger (2012)

The BOREAS legacy (1993-1996)







Outstanding carbon cycle questions

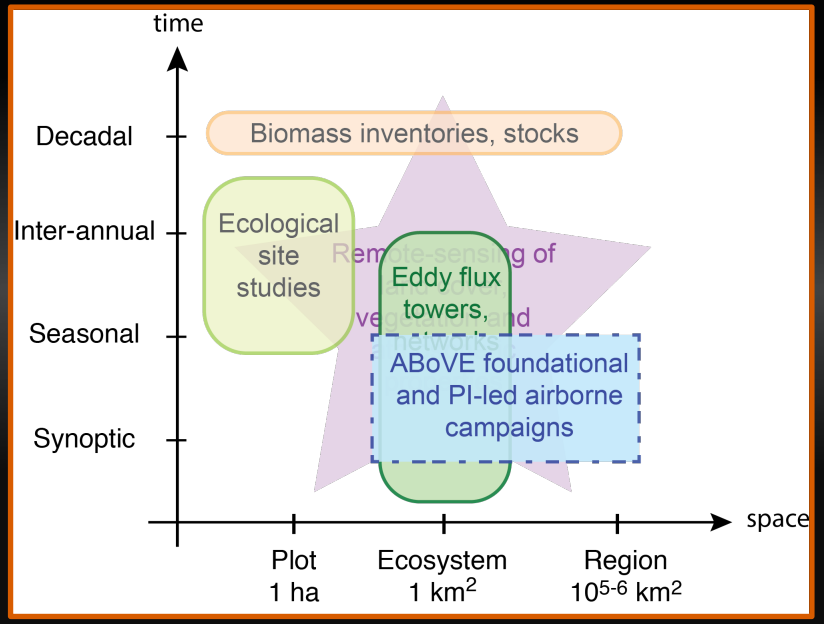
a) ABoVE (and Pan-Arctic) C budget

b) Reconciliation of C budget between bottom-up and top-down approaches

c) Seasonality and IAV in C fluxes, trends and future trajectories

d) Individual process dynamics (vegetation, permafrost, hydrology, disturbance) and contribution to C fluxes

e) Future natural and anthropogenic C emissions



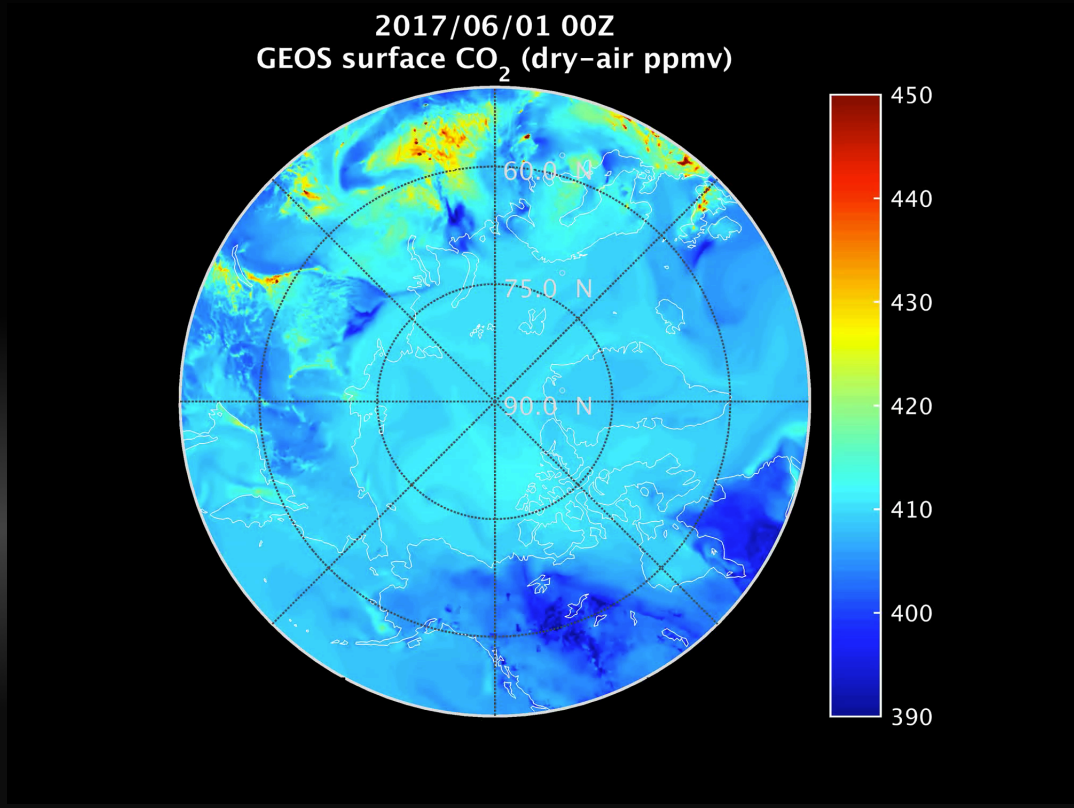
Recent Project Updates (as submitted by PIs and/or their teams)

- ✓ modeling
  - large-scale concentrations & fluxes … Chatterjee, Parazoo, Rogers
  - local scale … Munger
- ✓ observations
  - aircraft … Sweeney
  - flux towers … Natali
- ✓ carbon-permafrost … Turner

- Goal :

  Current ABoVE and Pan-Arctic C budget, RECCAP-2 tasks, Forecasting CO_2/CH_4 emissions

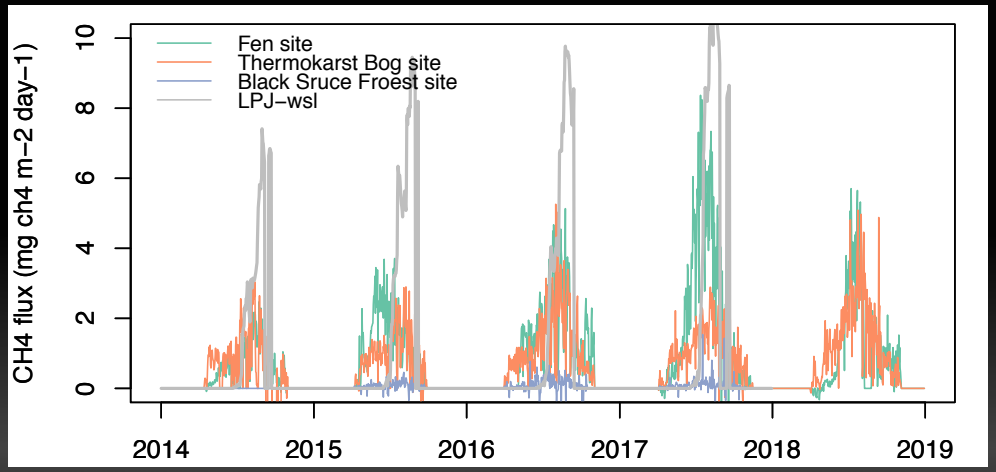
- GEOS-LPJ model - coupled land-ocean-atmosphere system running at ~12.5 km -to- 0.5° that simulates carbon species simultaneously (CO_2, CH_4, CO)
- Modeling effort recognizes the Arctic as a tightly coupled system

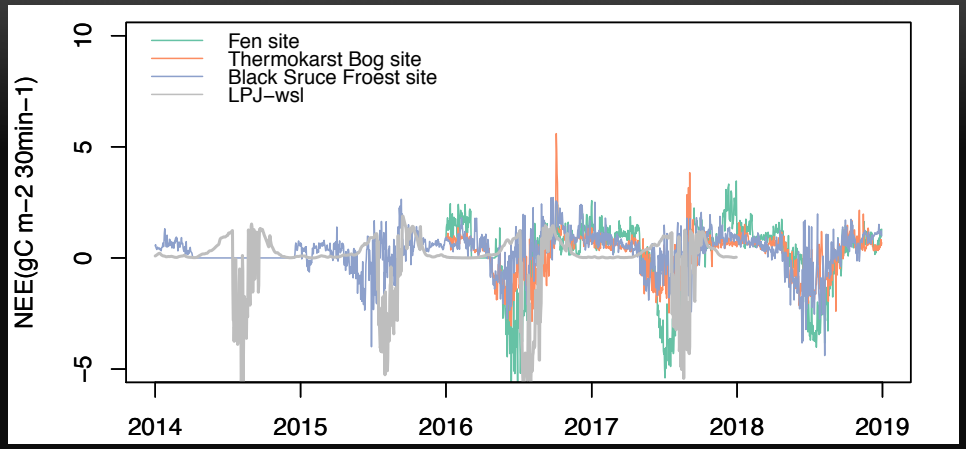


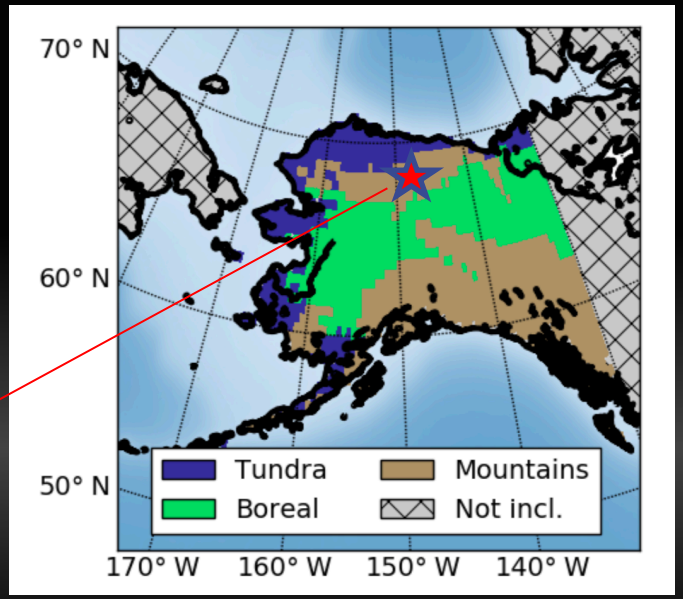
Global 12.5 km simulation for June 2017

(Chatterjee -01) Abhishek Chatterjee, B. Poulter, J. Masek, L. Ott, C. Miller, E. Euskirchen

Comparison with EC measurement at site level







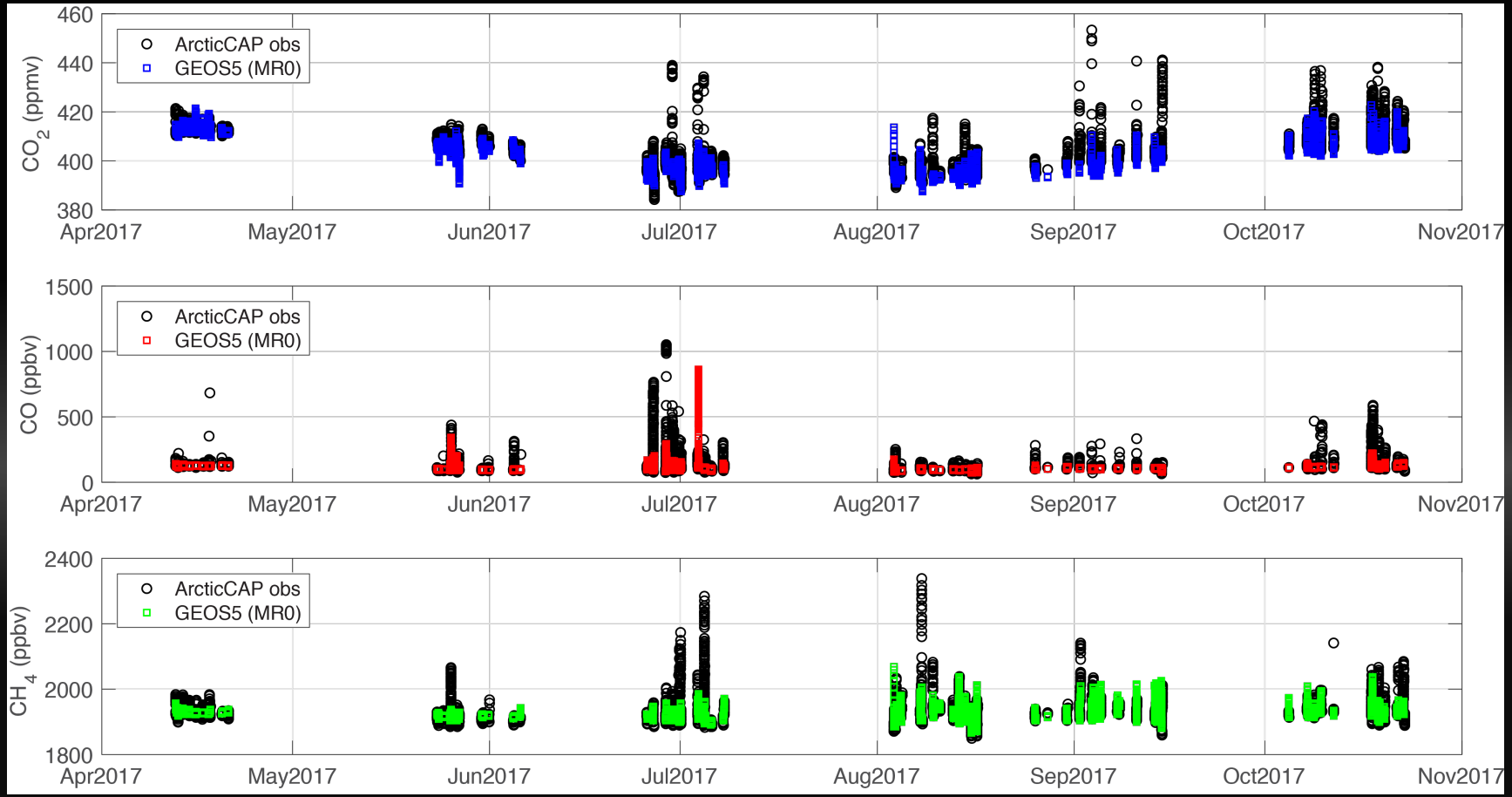
Hartery et al., 2018

(Chatterjee - 01) Zhen Zhang, B. Poulter, E. Euskirchen, A. Chatterjee

CO_2

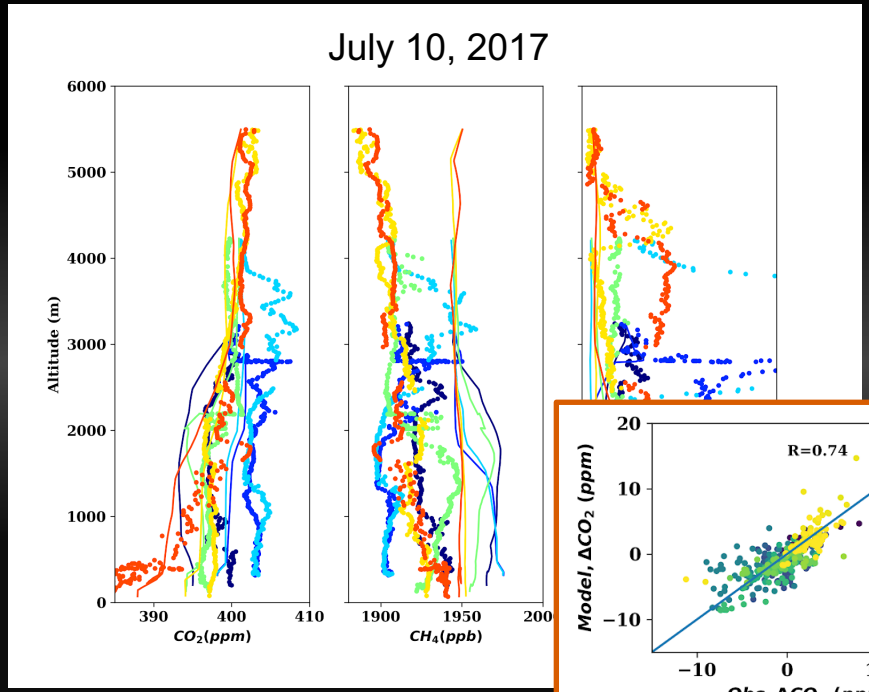
CO

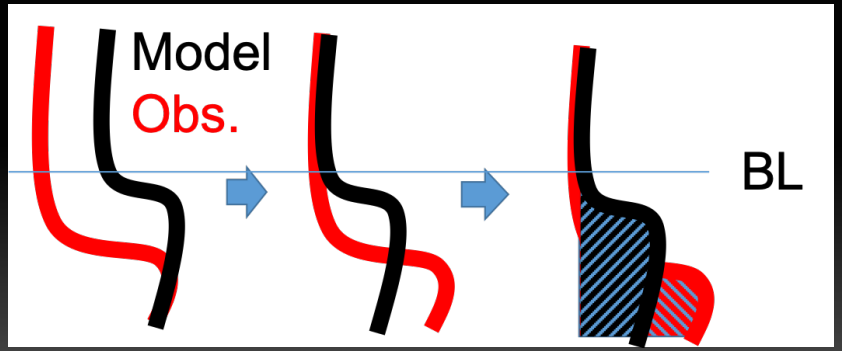
CH_4

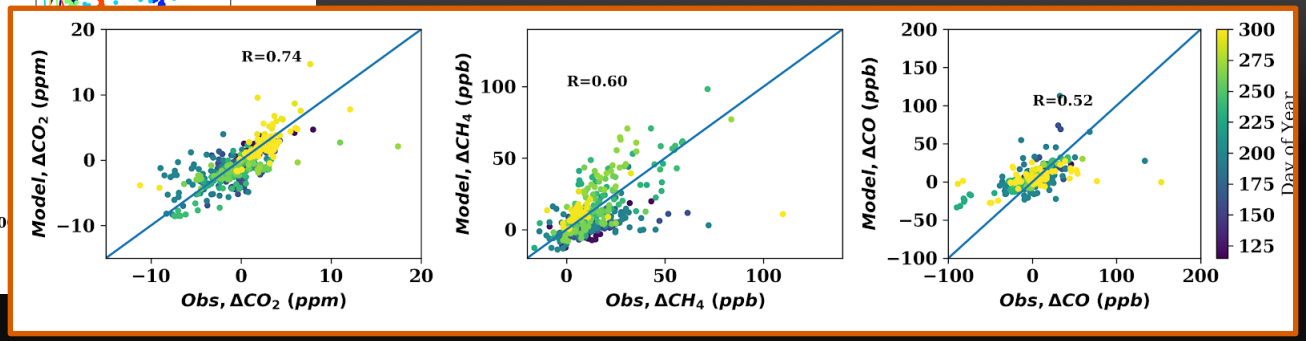


(Chatterjee-01, Sweeney-01) also see Colm Sweeney's poster, paper in prep. for ERL

A Tale of Three Carbon Species







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Different seasonal compensation between productivity and net carbon uptake during warm spring year

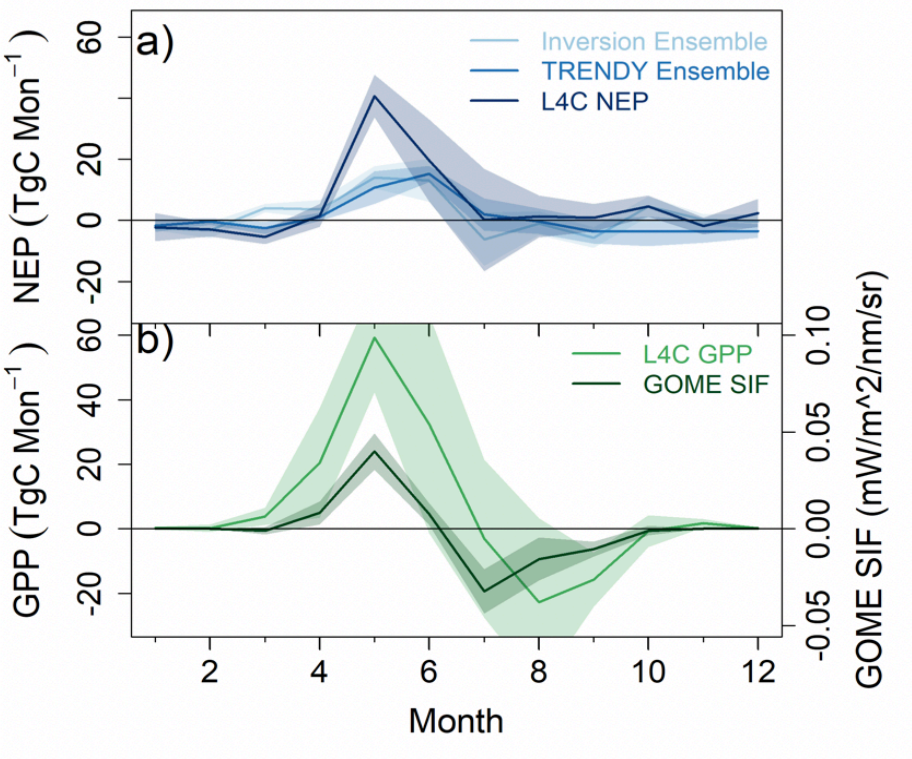


Figure 1. Seasonal carbon cycle anomaly across the ABoVE domain for a) net ecosystem production (NEP = GPP - TER), calculated as the difference between gross primary production (GPP) and terrestrial ecosystem respiration (TER); b) satellite based observations of ecosystem productivity represented by GPP from the NASA Soil Moisture Active Passive (SMAP) Level 4 Carbon (L4C) product, and solar-induced chlorophyll fluorescence (SIF) from the ESA GOME-2 sensor. The anomaly was calculated as difference between warm spring (2015/2016) and baseline (2010-2014) conditions. The inversion ensemble includes Carbon Tracker (CT2017), Carbon Tracker Europe (CTE2016), CAMS, Jena CarboScope (s76_v4.2 and s85_v4.2), and JAMSTEC. TRENDY ensemble includes CABLE, CLM4.5, JULES, LPJ, LPX, OCN, ORCHIDEE-MICT, and SDGVM using "S3" storyline that includes time-varying atmospheric CO2 concentrations, climate, and land-cover changes and management. Shading denotes 1 spatial standard deviation (SD) from the regional monthly means within the ABoVE domain.

Liu et al., **Increased photosynthetic carbon gain offset by preceding respiration carbon loss in anomalously warm winter to spring transition at high latitude**, *submission for environmental research letters*.

Contact:
Zhihua Liu (Zhihua.liu@mso.umt.edu), John Kimball (John.Kimball@mso.umt.edu), or Nick Parazoo (nicholas.c.parazoo@jpl.nasa.gov)

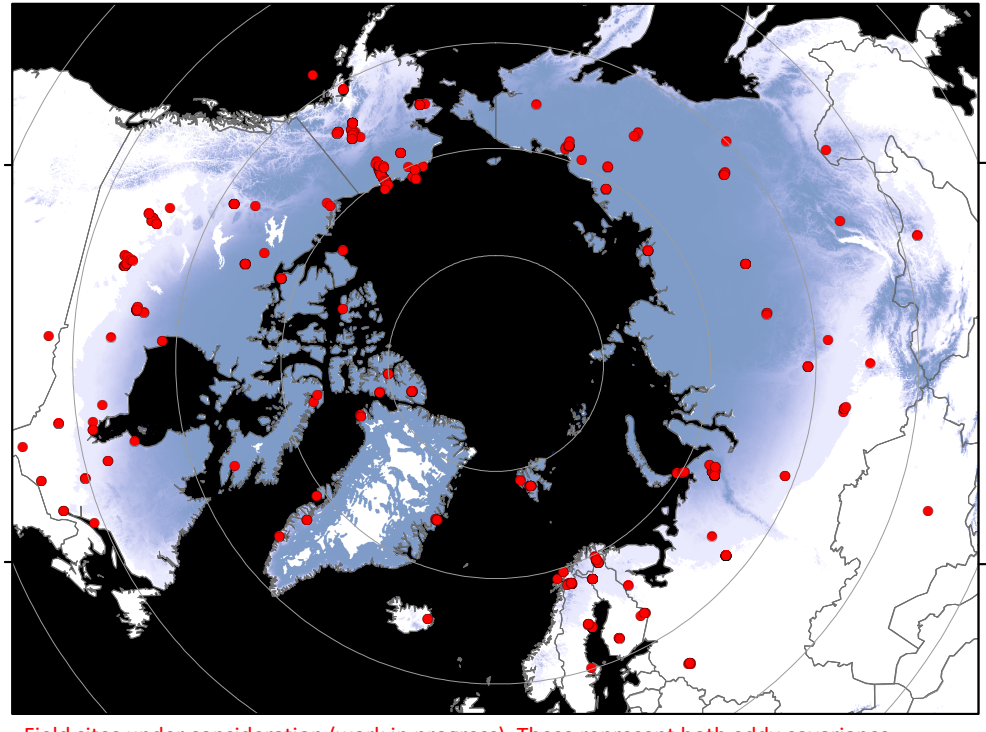
Rogers 02 (CARBON 2016): Multi-scale assessments of changing seasonal CO_2 fluxes across the arctic-boreal zone
Synthesis of *in situ* CO_2 fluxes

Objective
- Generate a new database and upscaled product for monthly CO_2 fluxes across the arctic-boreal zone
- Building on Natali et al. (*Nature Climate Change*, in review)

Methodology
- Compile & synthesize available *in situ* observations from publications, flux repositories, and researcher contributions
- Upscale to circumpolar gridded monthly product using remote sensing & other geospatial data sets
- In partnership with broader community efforts (Arctic Data Center-sponsored workshops in 2018)

Uses
- Assess spatial patterns and drivers of changing seasonal CO_2 fluxes and regional source / sink strengths

High-latitude CO_2 flux workshop at NCEAS, Santa Barbara, CA, March 2018



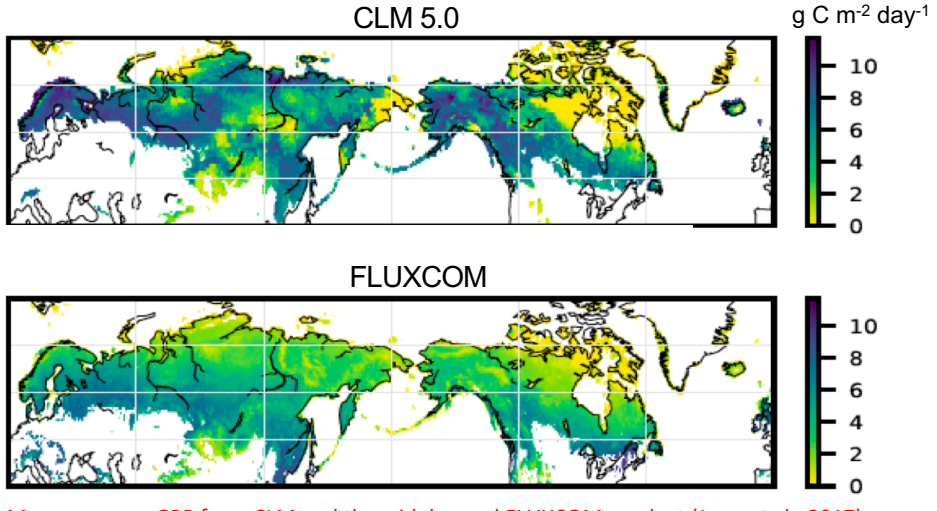
Field sites under consideration (work in progress). These represent both eddy covariance towers and chambers

Rogers 02 (CARBON 2016): Multi-scale assessments of changing seasonal CO_2 fluxes across the arctic-boreal zone
Prognostic land modeling (Community Land Model)

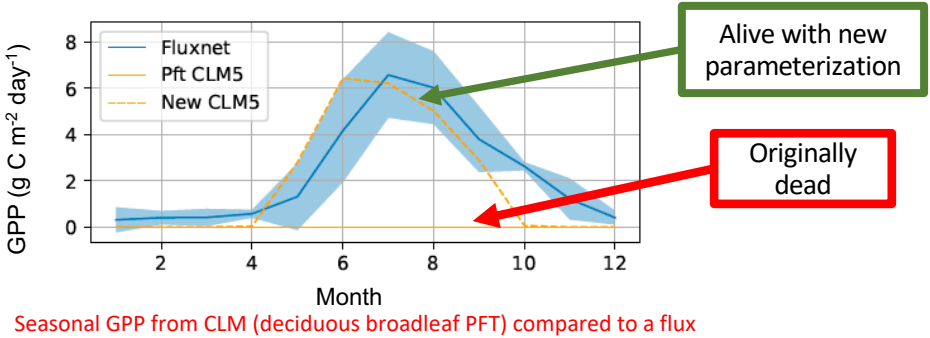
Objective
- Conduct a series of (NASA) data-driven model experiments to assess the underlying drivers of changing seasonal fluxes

Methodology
- Refine CLM to adequately represent high-latitude seasonal CO_2 fluxes, especially from individual Plant Functional Types (PFTs)
  - Focus on photosynthesis onset, offset, peak month, and magnitude
- Develop an experimental framework and drive historical simulations using gridded products (snow cover, vegetation properties, etc.)

Status
- CLM 5.0 compared relatively poorly with observations
- We have made progress on new algorithms for spring and fall phenology, and are developing a parameter optimization framework for GPP magnitude (Birch et al., *in prep*)



Mean summer GPP from CLM and the widely-used FLUXCOM product (Jung et al., 2017)



Seasonal GPP from CLM (deciduous broadleaf PFT) compared to a flux tower in southern boreal Canada (CA-QC2)

Rogers 02 (CARBON 2016): Multi-scale assessments of changing seasonal CO_2 fluxes across the arctic-boreal zone
Atmospheric transport

Objective

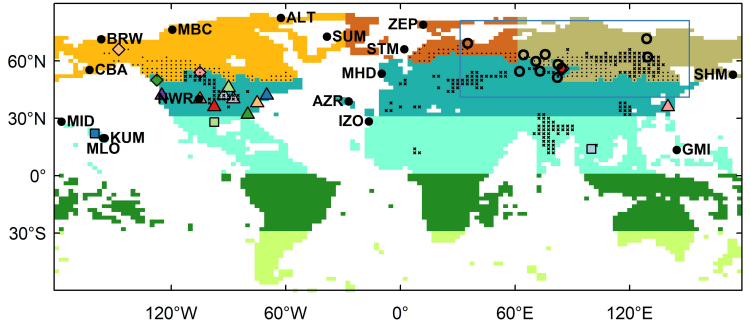
- Assess regional contributions to increasing CO_2 seasonal cycle amplitude (SCA)

Methodology

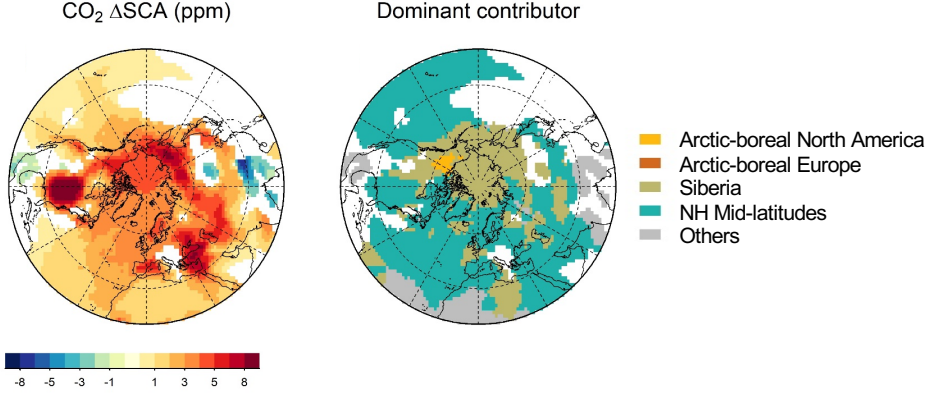
- Use a long-term CO_2 inversion product for surface fluxes (CAMS) and atmospheric transport model (GEOS-Chem)

Results

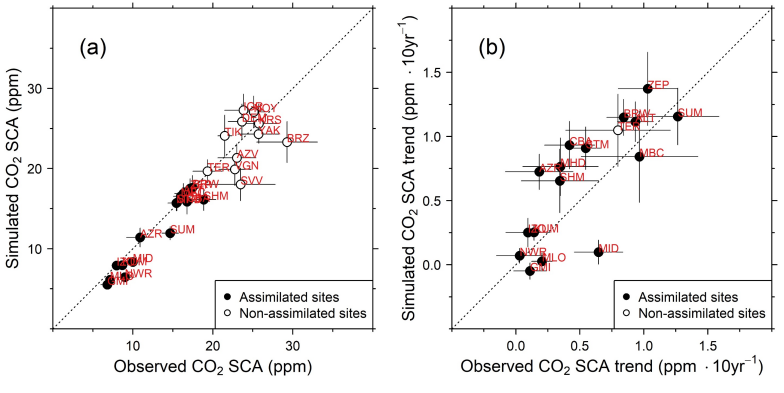
- The models adequately represent the magnitude, trend, and vertical gradient of the SCA at withheld observation sites
- Siberia dominates the increasing trends in SCA at the surface across the arctic-boreal zone (coinciding with widespread 'greening') (Lin et al., *in prep*)



Regions used for tagged CO_2 tracer transport simulations (blue box represents validation sites for Eurasia/Siberia)



Trend in SCA (1980-2017) at the surface and dominant contributing regions

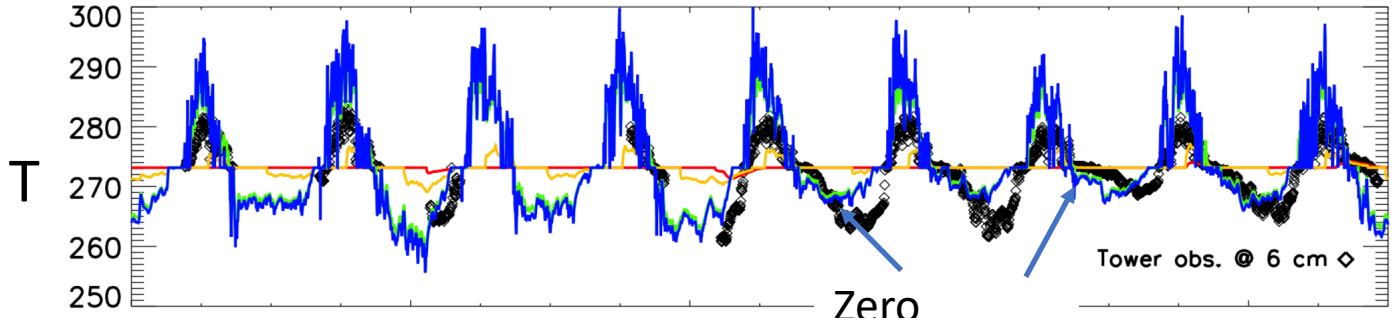


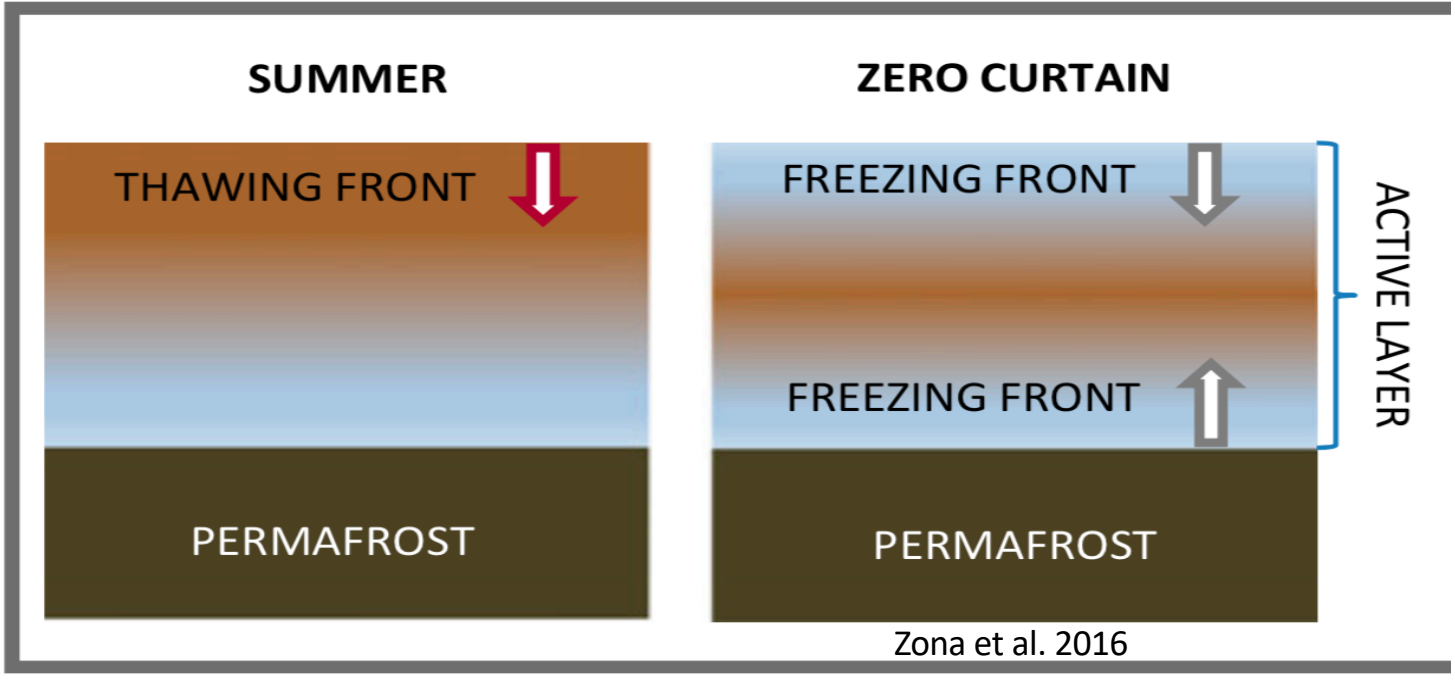
Model performance of CO_2 SCA and its trend at withheld validation sites across Eurasia and Siberia

2 cm
9 cm
40 cm
96 cm

Toolik Lake, AK tundra simulations

Vertically resolved, energy, moisture and respiration in ED2

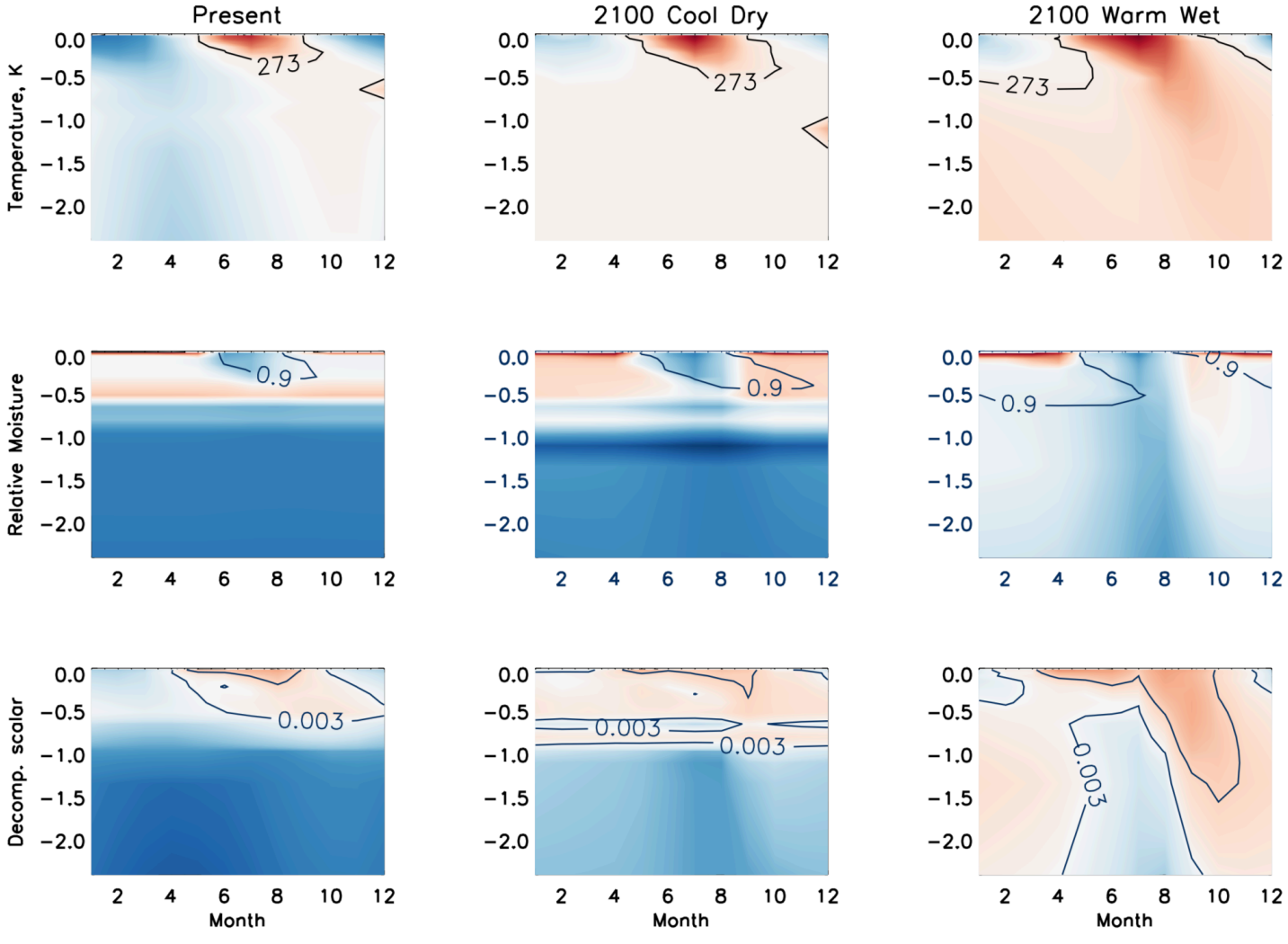




Zona et al. 2016

Larson, Moorcroft, Munger-04

- Deepening of active layer and zero curtain extension later into the winter/spring.
- Soil drying in the summer due to plant activity.
- Increased heterotrophic respiration in the fall/winter. Not in the summer – highlights need for year around measurements.



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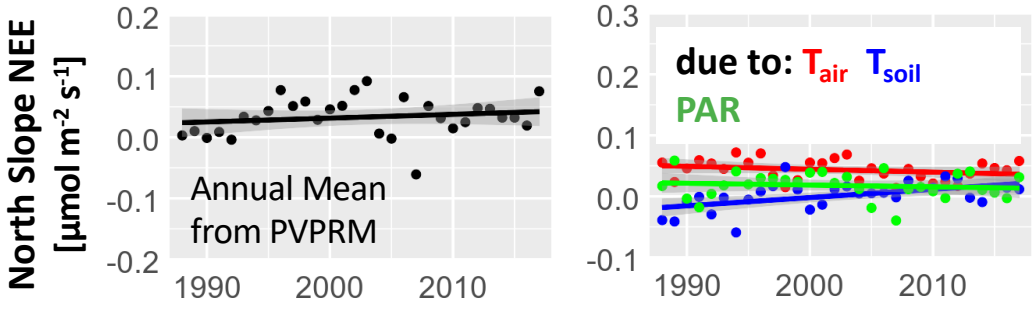
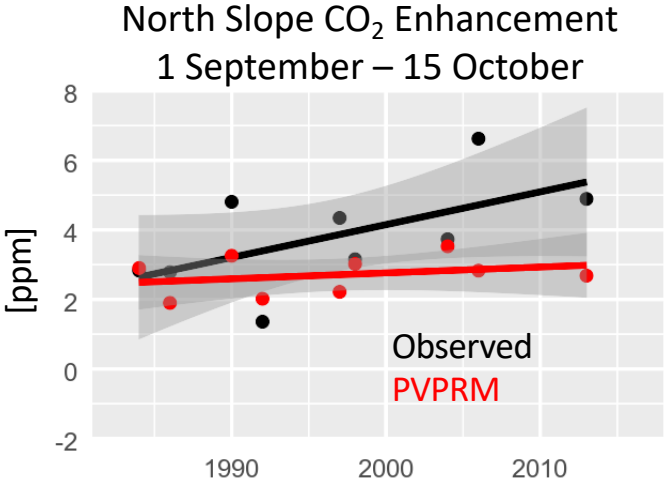


Simulated increased respiration from warmer soils is greater than increased uptake from warmer air temperatures.

Model underestimates observed increasing fall CO_2 enhancement trend at Barrow. Could be driven by missing processes, namely soil moisture.



[Schiferl et al., in prep]

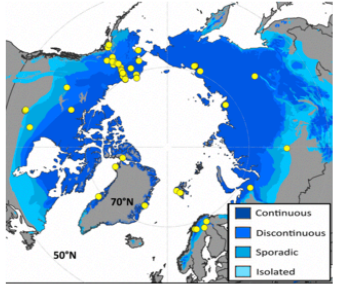
Munger-004 (Carbon 2016)

Winter Respiration Group Update

S. Natali, J. Watts, C. Minions, S. Ludwig, B. Rogers, S. Goetz & Collaborators

ABoVE ARCTIC BOREAL VULNERABILITY EXPERIMENT

Pan-Arctic Flux Synthesis



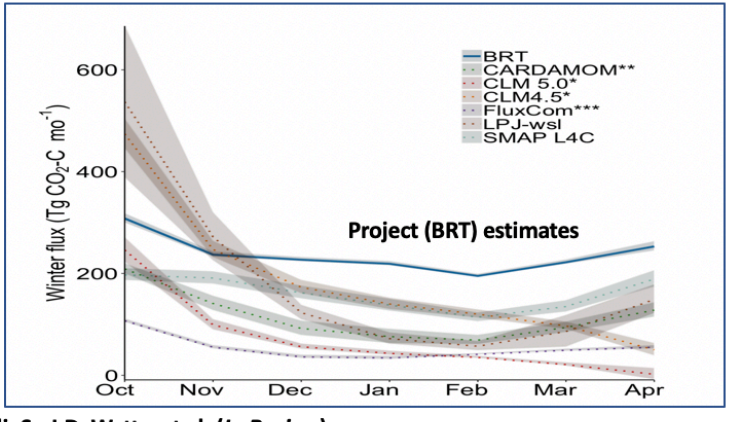
- New synthesized record of over 1,000 soil CO_2 observations from eddy covariance, chambers…
- Fluxes scaled to permafrost domain using remote sensing & Boosted Regression Trees (BRT); compared with process model estimates.
- ***Flux observations and resulting 25 km (monthly) flux maps submitted to ORNL-DAAC.***

Key findings:

1) pan-Arctic winter CO_2 emissions (2003 to 2017) avg. 1,662 Tg C $year^{-1}$;

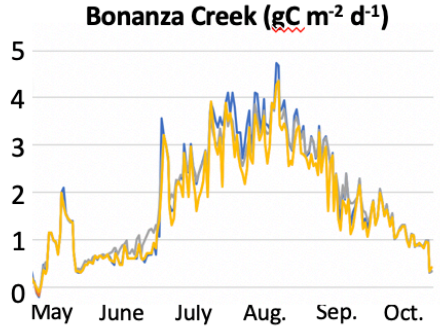
2) Fluxes of > 0.25 gC m^{-2} day, even during cold (< -5ºC) soil conditions;

3) Many process models underestimated CO_2 loss during the cold seasons, relative to *in situ* flux observations and BRT based estimates.

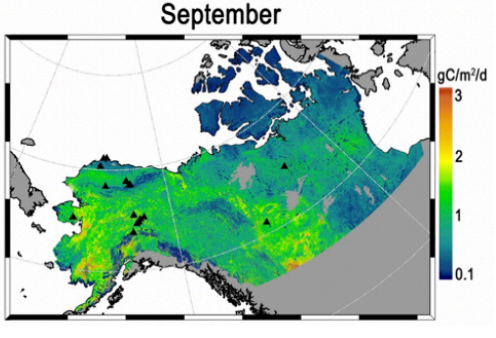


Natali, S., J.D. Watts, et al. (*In Review*)

ABoVE Soil Respiration Stations (SRS)



- ***New record (2016 to ≥ 2018) of hourly soil CO_2 flux from 11 sites in Alaska (1 in Canada)***, obtained from forced diffusion chambers. Includes summer, shoulder and winter seasons. ***Recently submitted to ORNL DAAC.***
- The SRS database includes hourly soil temperature (5, 15, 25, 50 cm depths) and soil moisture at 15 cm depth; daily site photos; snow depth; active layer.



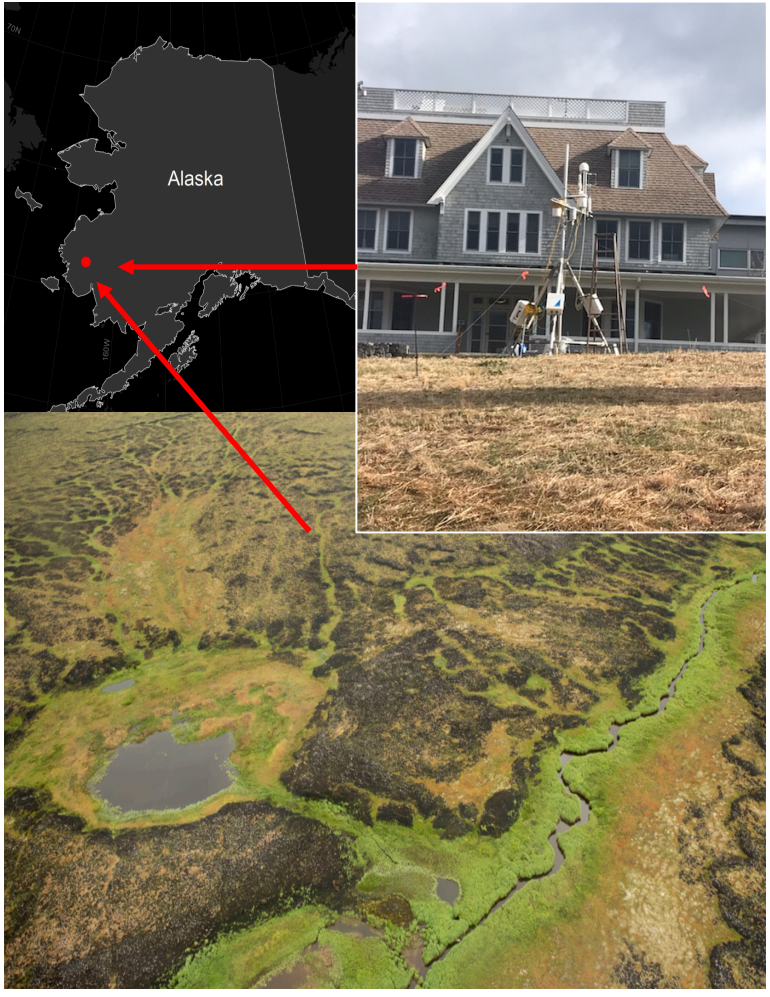
- The SRS fluxes + eddy covariance used with remote sensing & machine learning to produce ***monthly flux maps at 300 m res for ABoVE domain***.
- **ABoVE cold season flux budget (Sept. though Mar.) ~ 140 Tg C (2016/2017)**

New Eddy Covariance Tower in Yukon-Kuskokwim Delta

Woods Hole Research Center

PI: Sue Natali (WHRC)

ABoVE Arctic Boreal Vulnerability Experiment



- New flux tower (CO_2, CH_4) sponsored by WHRC will be installed summer 2019.
- Chamber fluxes also planned in burned (2015 fire) and unburned tundra.
- Observations will provide important validation for models and airborne.

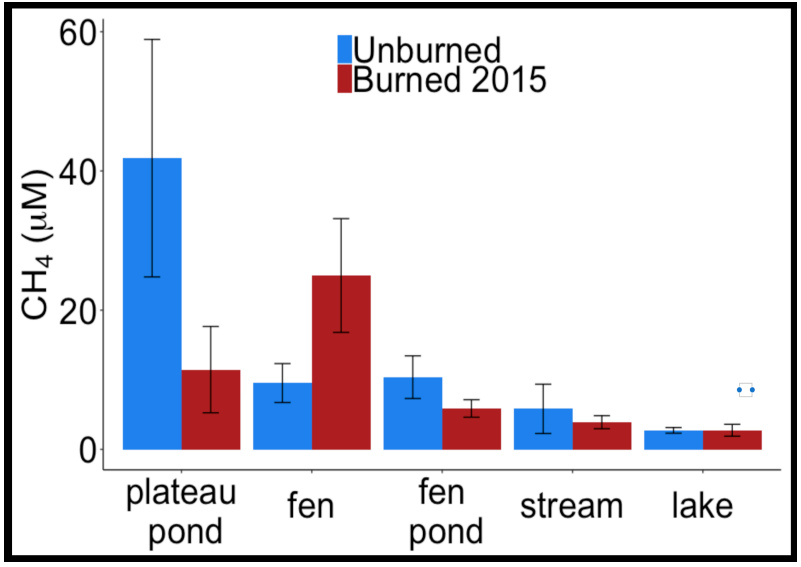


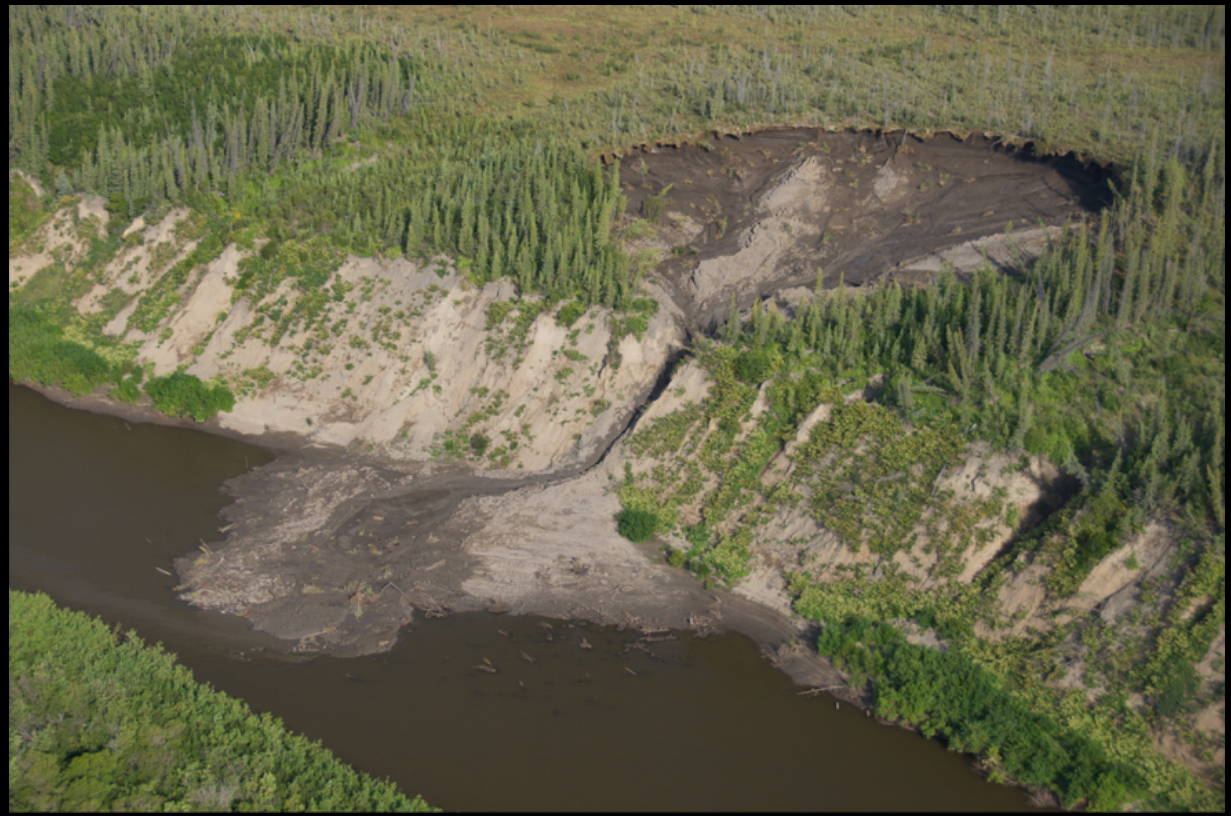
Figure from S. (Ludda) Ludwig

Old Crow Flats, Yukon

Dr. Kevin Turner, Brock University

In prep (during sabbatical!)

- Impacts of permafrost slumping along the Old Crow River, Yukon
- Evaluating sources for river carbon export from Old Crow Flats, Yukon using $\delta^{13}C$



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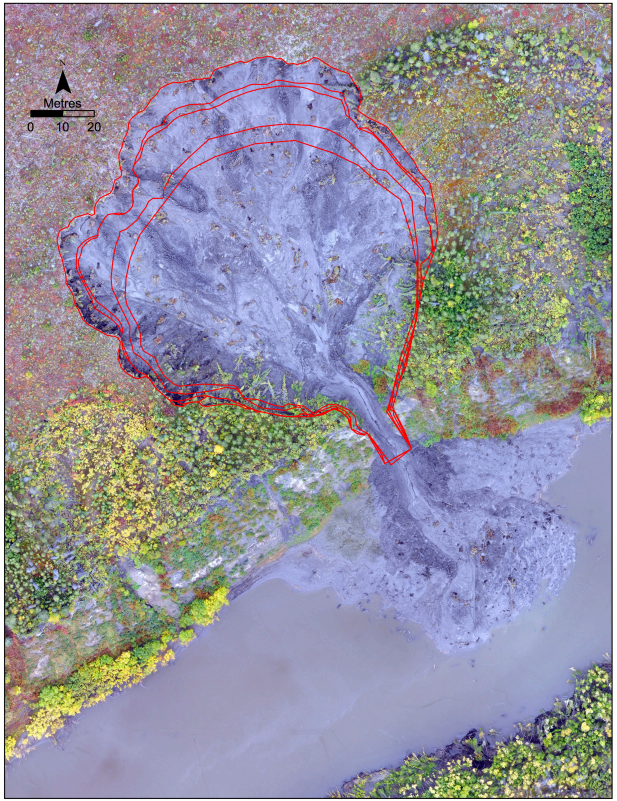
Completed analyses

- UAV surveys and volumetric analysis of slump 2016-18
- Slump sediment C, N, bulk density analyses
- Lake and river water C (DIC, DOC) concentration and d13C analyses across 14 lakes and 24 river and creek sites



Fieldwork

June and August 2018:

- Water sampling lakes and rivers for isotope and other biogeochemical analyses
- UAV surveys at Zelma Lake, permafrost slump and burn

June 2019:

- UAV inventories of permafrost slumping along Old Crow River
- Slump sediment sampling for C analyses
- Water sampling lakes and rivers for isotope and other biogeochemical analyses
- Lake sediment coring to reconstruct lake responses (including C) to changing catchment characteristics

Summary

- "How are the magnitudes, fates, and land-atmosphere exchanges of carbon pools responding to environmental change, and what are the biogeochemical mechanisms driving these changes?"
- CDWG must continue - Phase 2 and beyond
- Looking forward (2019-2020 strategic plan): rescope coordination & synthesis activities (**discussion topic for today's breakout**), projects & WG need to be updated, synergy with PCN/SEARCH, NGEE-Arctic, IARPC

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